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SUBJECT: A Method of Depicting Lunar Surface EVA's, Illustrated for the Apollo 14 Mission - Case 320

DATE: January 26, 1971

FROM: J. C. Slaybaugh

ABSTRACT

Recent reviews of the Apollo 14 lunar surface mission have led to the development of two tools which are useful for evaluating planned lunar surface EVA's: (1) an EVA Activities Sequence Chart - a quantitative, semi-detailed listing of EVA activity times and sequences, similar in content to the Lunar Surface Procedures - and (2) an EVA Time History - a graphic presentation of traverse distance from the LM versus elapsed EVA time. Discussion of these tools is illustrated with the Apollo 14 Mission.

The Activities Sequence Chart has proved useful as the basis for an uncertainty analysis of Apollo 14 metabolic expenditures, as well as for a tabulation of cumulative time spent on various types of EVA activity. The Time History provides a format useful for evaluating operational margins for both nominal and extended EVA's. Two possible extensions to the first EVA on Apollo 14 have been examined and found to be operationally feasible.

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MEMORANDUM FOR FILE

INTRODUCTION

Various techniques are currently in use to describe planned crew activity sequences on the lunar surface. Among the more common of these are summary timelines, the Lunar Surface Procedures, and traverse maps. While each of these methods has its advantages when used as a tool for mission planning, each also has its limitations when used to evaluate the mission once it has been planned. The Surface Procedures provide thorough, quantitative timeline information but are too detailed for many broad scale review tasks. Summary timelines are readily amenable to qualitative reviews, but lack the quantitative detail provided by the Surface Procedures. Traverse maps, while representing the physical excursions of the crewmen, provide little information about activity times and sequences.

Recent reviews of the Apollo 14 surface mission have led to the development of two further tools for use in understanding and evaluating the missions: (1) an Activities Sequence Chart, similar in content, but less detailed than the Lunar Surface Procedures, and (2) an EVA Time History, which combines the linear characteristics of a traverse map and the temporal characteristics of a timeline. The advantages of each of these representations is discussed below in a brief review of the Apollo 14 surface mission.

FORMAT

<u>EVA Activities Sequence Chart</u> - Figure 1 is a schematic representation of the traverse planned for the first EVA on Apollo 14. As such, it is typical of the various maps used for mission planning purposes. Although it provides a convenient frame of reference in a familiar form, its lack of time scale has significant drawbacks. To furnish the additional data, the EVA Activities Chart shown in Figure 2 was constructed from the detailed information contained in the Lunar Surface Procedures [1]. Activities of durations ranging from three to twenty-five minutes were identified and listed sequentially for each crewman. In addition, an EVA time scale was included to allow correlation of activity performance with elapsed EVA time.

Used in conjunction with a traverse map such as Figure 1, the Activities Chart can provide a quantitative overview of the entire EVA. Employed separately, it can be used to evaluate various facets of the surface mission. As shown in Figure 3, a cumulation of time spent on various activity categories for the EVA can readily be tabulated from the Activities Chart. The categories and times shown are clearly not unique, but do serve to illustrate the utility of such a quantitative measure of the EVA.

A slightly modified form of the Activities Chart was also used as the basis for a metabolic uncertainty analysis [2,3]. In this study, each major activity during the EVA was classified into one of five metabolic rate categories, and total metabolic energy computed by cumulation of the separate activity costs. The format of Activities Chart is such that the required base data was readily available.

<u>EVA Time History</u> - Together, the EVA Activity Chart and a traverse map provide a quantitative overview of both the spatial and temporal aspects of an EVA. It would be more convenient, however, if this information could be combined on a single chart. Figure 4 is one approach to this problem.

Travel distance from the LM has been plotted against time, in an EVA Time History. In this format, a sloping line segment represents travel radial to the LM (increasing slope magnitude corresponding to increasing travel speed), and a horizontal segment represents either activity at a single station or travel normal to a radius from the LM. Various activities have been indicated on the traverse with corresponding surface priorities noted for each.

The consumables limit line in Figure 4 represents the maximum distance the crew can be from the LM at any point during the EVA and still be able to return safely to the LM, with thirty minutes reserve and thirteen minutes for ingress. Oxygen was used as the limiting consumable, and an average metabolic rate of 1050 Btu/hr was assumed up to the point of return. Since the limit is clearly a function of assumed metabolic rate, a similar line has been constructed for 1200 Btu/hr to show sensitivity. In both cases, return to the LM was assumed to be walking at 3 ft/sec (1200 Btu/hr). It should be noted that the limit shown does not represent the time-history of the crew during an emergency return, but rather a series of points from which the crew would have to return directly to the LM.

Among the advantages inherent in such a representation are its:

(1) simultaneous presentation of spatial and temporal data
(2) quantitative measure of activity times and distances
(3) visual presentation of margins with respect to mission duration and return distance constraints
(4) visual measure of consumables margins.

Among the disadvantages of the Time History is the ambiguity which exists in interpreting a horizontal line segment. Since the vertical axis measures radial distance from the LM, a horizontal line can represent either a traverse normal to a radius from the LM, or activity at a single station. To clarify this ambiguity, science activities at a station have been identified with a broken line.

In addition to the usefulness of the Time History for reviewing the nominal mission, the visual display of margins with respect to time, distance and consumables, makes it particularly suited to analyses of perturbations from the nominal mission. In considering possible extensions to the EVA, for instance, the 4+15 nominal duration constraint would be displaced to the right to show an extended mission envelope. Similarly, an EVA running ahead of or behind the nominal timeline could be depicted by displacing the time scale to the right or left from the point of departure.

Figure 5 illustrates a forty-five minute extension to EVA 1, with candidate traverses around Doublet, and to Star Crater Rim. In this case, the point of extension occurs at Station U in the EVA. A brief comparison of the two traverses shown in the figure discloses that although Star is approximately a twelve minute walk from the LM, the nominal timeline already provides for:

(1) a traverse from the LM to Station U ($\sim$5 minutes)
(2) fifteen minutes geology time at Doublet
(3) a traverse from station W back to the LM ($\sim$3 minutes),

or a total of twenty-three minutes. Thus, if a forty-five minute extension were granted, and Doublet were not investigated, forty-four of those minutes could be spent at Star, with the rest of the travel time absorbed by the nominal timeline. As may be seen in the Time History, such a Traverse would not violate the constraints on consumables, EVA time, or return distance.

Figures 6 through 8 are the traverse schematic, Activities Chart and Time History respectively, for the second EVA. As may be seen by comparing Figures 1 and 6, the traverse for the second EVA is more nearly radial to the LM, and therefore presents less ambiguity on the Time History. Figure 7, the EVA Activities Chart, is the input used in the metabolic error analysis discussed above.

A comparison of Figures 4 and 8 points out several basic differences between the two EVA's. First, the operational envelope has been modified to reflect the use of the B-SLSS instead of the OPS. The limit on maximum return distance has been increased from 1 Km (3280 ft) to 3 Km (9840 ft). Although the PLSS consumables limit will also be a function of the B-SLSS, for the current discussion it is assumed essentially unchanged from the EVA 1 constraint.

Most obvious of the differences between the two Time Histories is their shape. The second EVA is designed to get the crew to the furthest point in the traverse early in the EVA, with most major scientific activity occuring after that point. The first EVA, by contrast, reverses the procedure, with the farthest traverse from the LM appearing late in the EVA. The philosophy followed in the second EVA is seen to provide greater margins with respect to the operational envelope.

Figure 9 shows the extension currently planned for EVA 2. Again a major difference is seen in the philosophy of the two EVA's. The extension planned for EVA 1 has its major impact on the spatial domain (vertical axis) of the Time History, while the extension of EVA 2 impacts the time domain (horizontal axis). In both cases, the margins with respect to time, return distance and PLSS consumables are clearly evident.

As familiarity is gained with the format of the Time History, EVA shapes and their implications become readily recongizable.

CONCLUSIONS

Two useful tools for evaluation of a planned lunar surface EVA have been described, using the Apollo 14 mission for reference. The EVA Activities Sequence Chart has proved useful when quantitative, semi-detailed information is required in an easily usable format. The EVA Time History has been useful for the simultaneous presentation of spatial and temporal EVA data. Although neither format is unique in the data presented, it is felt that each technique provides a useful tool for review and analysis of lunar surface missions.

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2032-JCS-tls

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1. "Apollo 14 Preliminary Lunar Surface Procedures, Revision A," 28 October, 1970.

2. Bottomley, T.A., "Basic Data for an Error Analysis, of Metabolic Energies During Lunar Surface EVA's," Bellcomm Technical Memorandum in preparation.

3. Gunther, P. "An Error Analysis, of Metabolic Energies During Lunar Surface EVA's," Bellcomm Technical Memorandum in preparation.

APOLLO 14 EVA 1

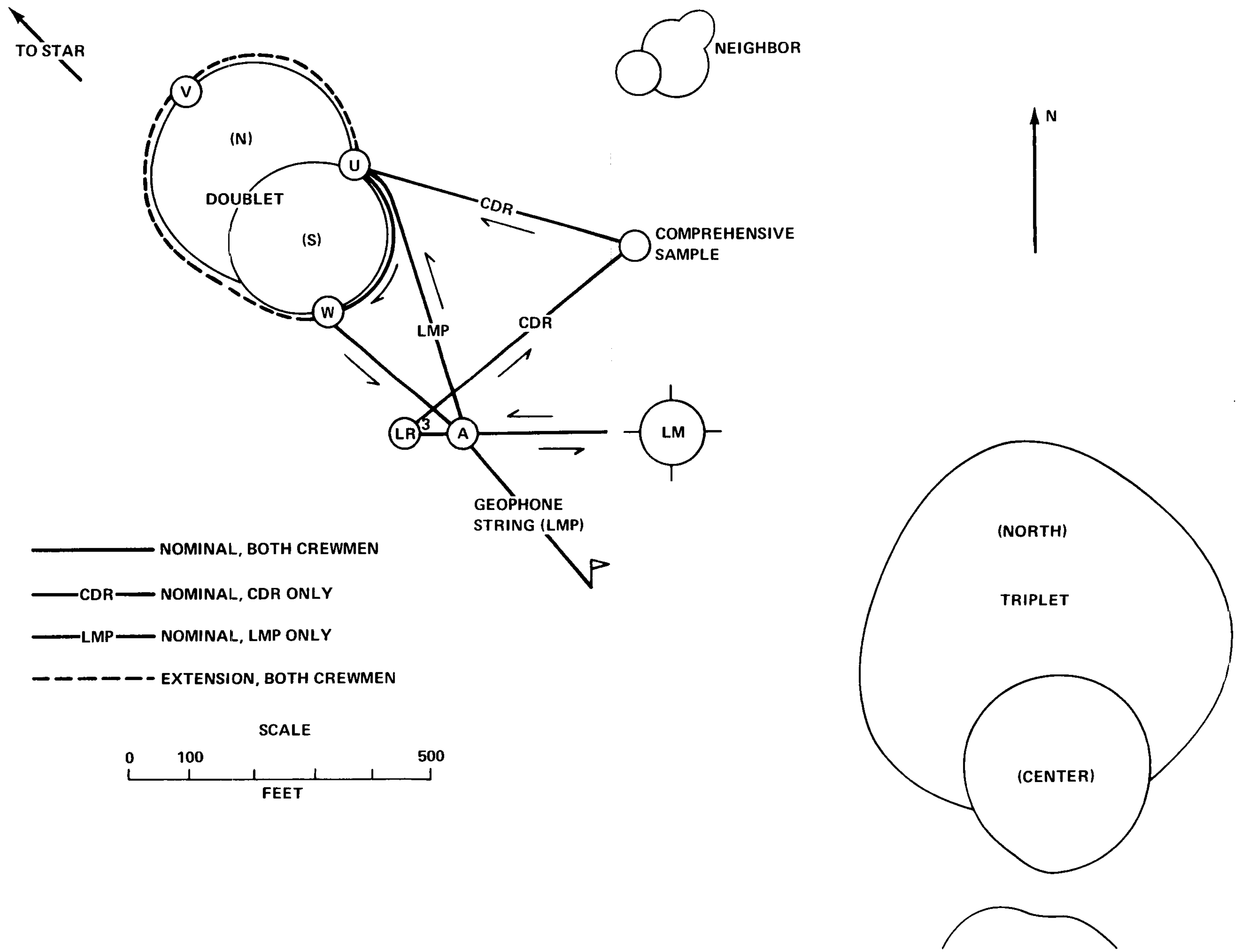


FIGURE 1

APOLLO 14 NOMINAL EVA 1 ACTIVITIES

EVA TIME	SITE	LMP ACTIVITY	TASK TIME	CDR ACTIVITY	TASK TIME
			AT LM (1 hr 44 min)		
0+00	LM	Pre-Egress Activities	10	Pre-Egress Activities	10
0+10		Assist CDR	8	Egress (Deploy LEC,MESA)	8
0+18		Egress	7	Familiarization	4
0+22				MET Offload	4
0+25		Familiarization	3		
0+26				Deploy TV	7
0+28		MESA Activities	5		
0+33		Contingency Sample	4	Deploy S-Band Antenna	17
0+37		Deploy SWC Experiment	4		
0+41		Offload LR^3	5		
0+46		Assist CDR	4		
0+50		Ingress, Switch S-Band, Egress,ETB Transfer	10	ETB Transfer	10
1+00		Deploy Flag	6	Deploy Flag	6
1+06		TV Pan	8	Photo Pan	8
1+14		MET Deploy	6	MET Deploy	6
1+20		Offload ALSEP	16	Offload ALSEP	16
1+36		MESA Activities	8	MESA Activities	8
1+44	LM-A	Travel (Carry ALSEP)	9	Travel (Pull MET)	9
			STATION A (1 hr 22 min)		
1+53	A	Site Survey & System Interconnect	17	Site Survey & System Interconnect	17
2+10		Offload Thumper/Geophone	4	Offload PSE	4
2+14		Deploy Mortar Package	7	Deploy Sunshield	11
2+21		Deploy CPLEE	5		
2+25				Install ALSEP Antenna	10
2+26		Deploy SIDE/CCIG	10		
2+35				Deploy PSE	7
2+42				Deploy LR^3	4
2+46		Deploy Geophones	14	Photo ALSEP	9
2+50		Thumper	25		
2+56				Comprehensive Sample	19
			DOUBLET (15 min)		
3+15	U,V,W	Geology Traverse	15	Geology Traverse	15
3+30		Return Traverse	5	Return Traverse (SAMPLING)	15
3+35	A	Activate Mortar Package	5		
3+40	A-LM	Return Traverse	5		
			AT LM (30 min)		
3+45	LM	EVA Closeout	17	EVA Closeout	25
4+02		EVA Terminate	13	EVA Terminate	5
			4+15		4+15

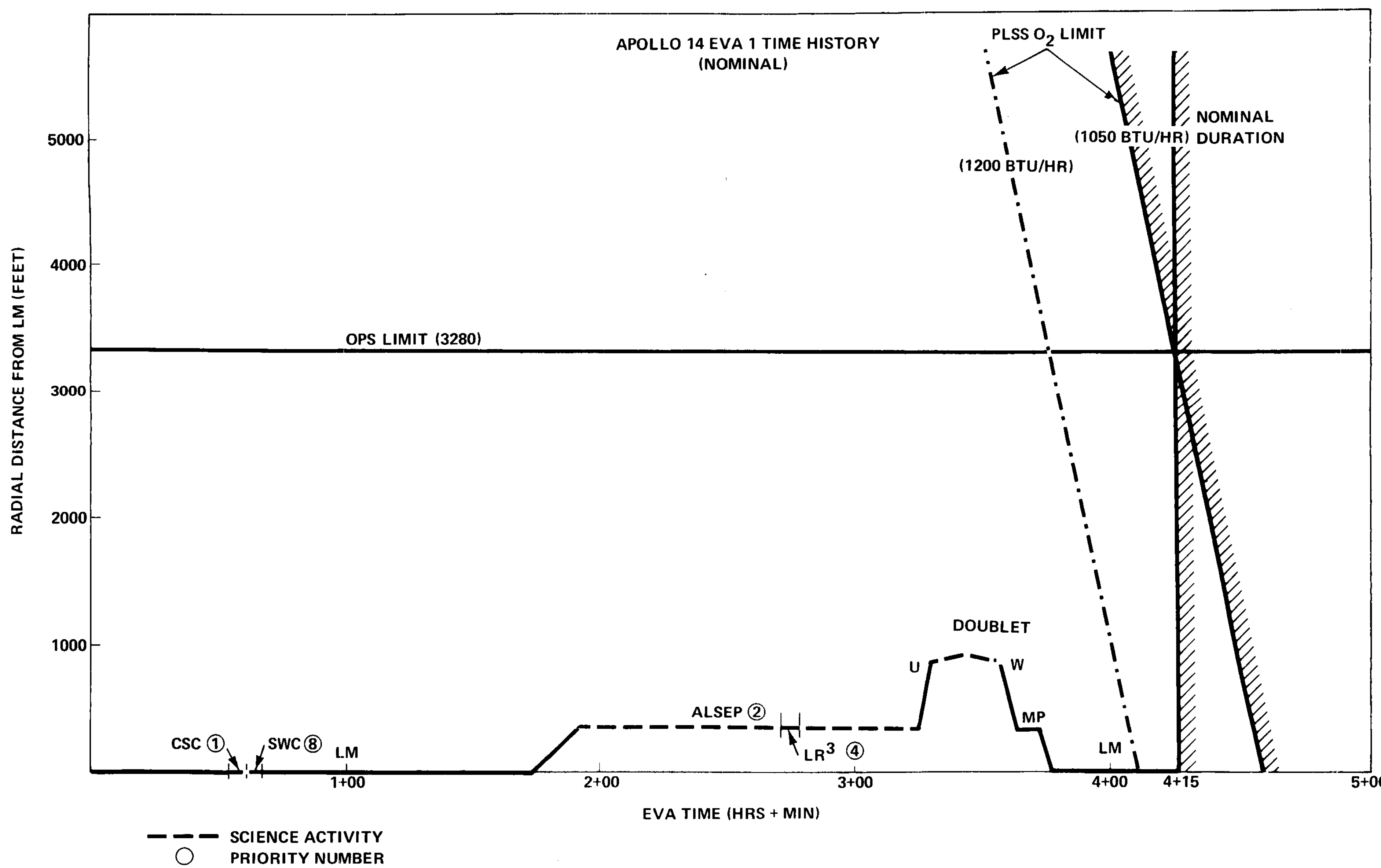
FIGURE 2

APOLLO 14 NOMINAL EVA 1

ACTIVITY TIME SUMMARY

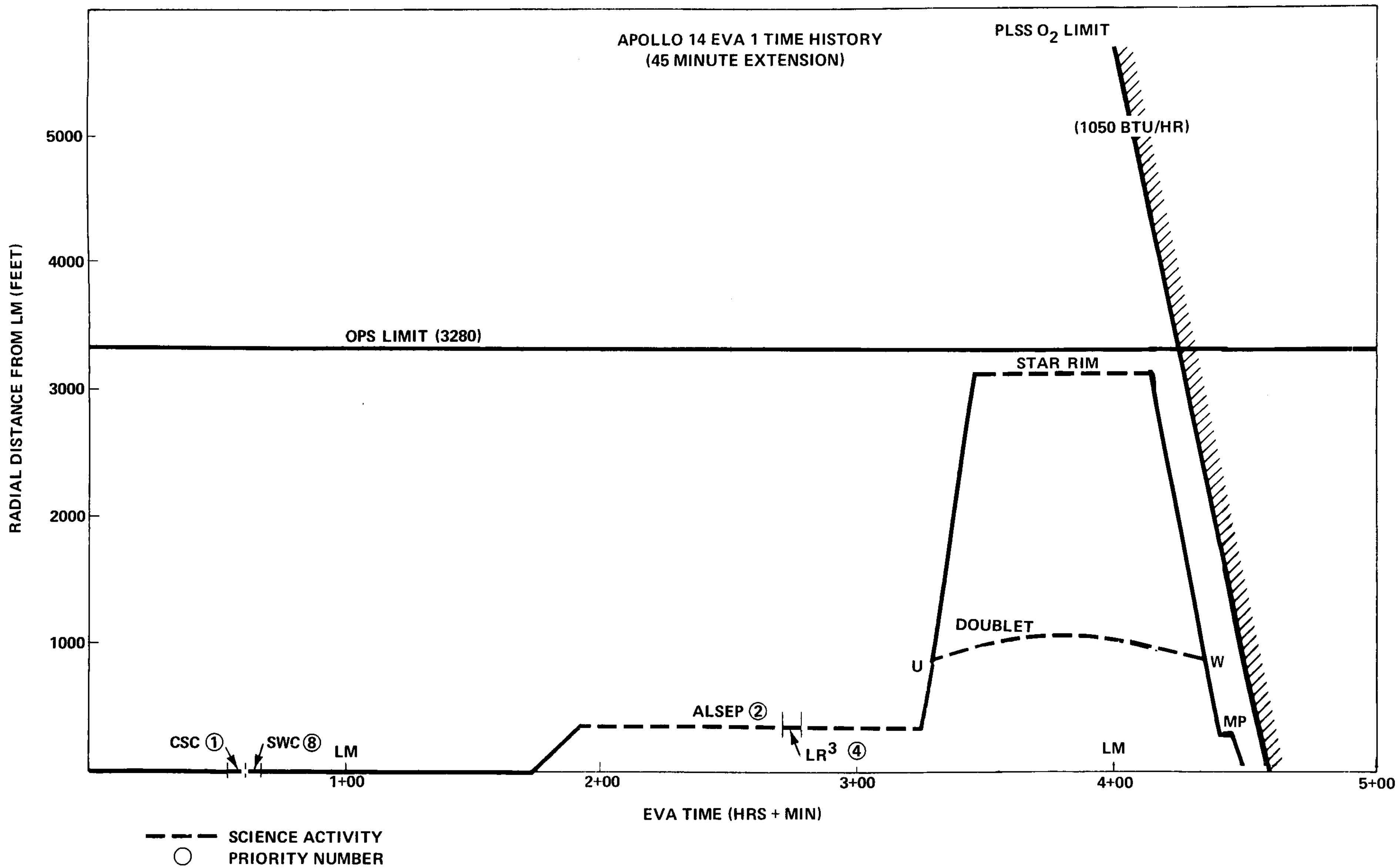
	LMP	CDR	TOTAL
HOUSKEEPING	1+37	1+50	3+27
SCIENCE	2+11	1+53	4+04
(ALSEP)	(1+43)	(1+15)	
(SAMPLE)	(0+19)	(0+34)	
(OTHER)	(0+09	(0)	
DESCRIBE/PHOTO	0+08	0+12	0+16
TRAVEL	0+19	0+24	0+43
OTHER	0	0	0
	4+15	4+15	8+30

FIGURE 3



APOLLO 14 EVA 1 TIME HISTORY
(NOMINAL)
PLSS O_2 LIMIT
(1200 BTU/HR)
(1050 BTU/HR)
NOMINAL DURATION
OPS LIMIT (3280)
RADIAL DISTANCE FROM LM (FEET)
5000
4000
3000
2000
1000
DOUBLET
U
W
MP
ALSEP ②
LR³ ④
CSC ①
SWC ⑧
LM
LM
1+00
2+00
3+00
4+00
4+15
5+00
EVA TIME (HRS + MIN)
SCIENCE ACTIVITY
PRIORITY NUMBER

FIGURE 4



APOLLO 14 EVA 1 TIME HISTORY
(45 MINUTE EXTENSION)
PLSS O2 LIMIT
(1050 BTU/HR)
OPS LIMIT (3280)
STAR RIM
DOUBLET
U
W
MP
ALSEP ②
LR3 ④
CSC ①
SWC ⑧
LM
LM
RADIAL DISTANCE FROM LM (FEET)
5000
4000
3000
2000
1000
1+00
2+00
3+00
4+00
5+00
EVA TIME (HRS + MIN)
SCIENCE ACTIVITY
PRIORITY NUMBER

FIGURE 5

APOLLO 14 EVA 2

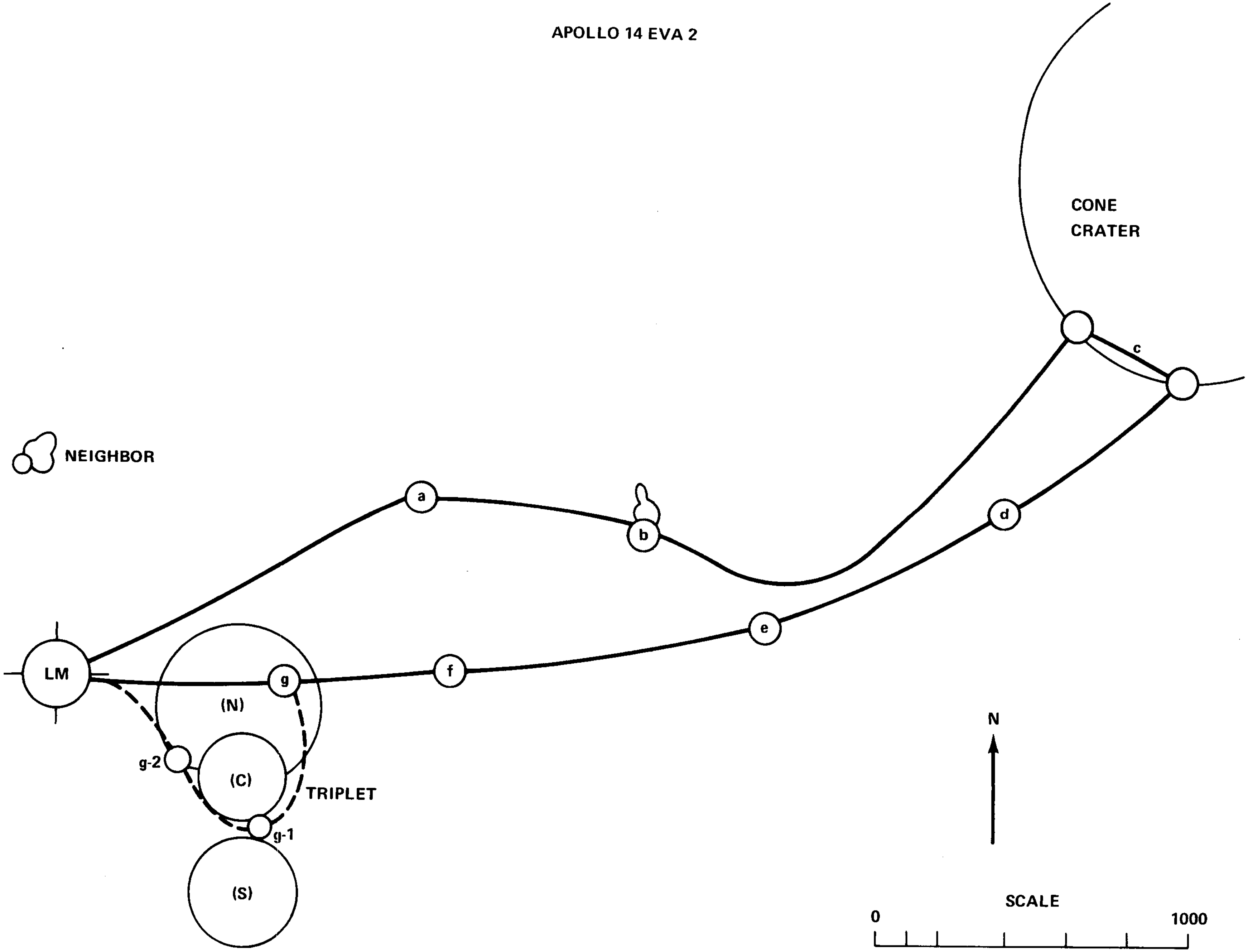


FIGURE 6

APOLLO 14 NOMINAL EVA 2 ACTIVITIES

EVA TIME	SITE	LMP ACTIVITY	TASK TIME	CDR ACTIVITY	TASK TIME	TRAVEL DIST (FT)
			AT LM (35 min)			
0+00	LM	Pre-Egress Operations	10	Pre-Egress Operations	10	
0+10		Assist CDR	5	Egress	5	
0+15		ETB Transfer	5	ETB Transfer	5	
0+20		Egress	5	MET Load	15	
0+25		Assist MET Load	10			
0+35		Travel (4 fps)	6+	Travel (4 fps)	6+	1300
			STATION a (26 min)			
0+41	a	LPM Measurement	19	Therm.Degrad. Sample	9	
0+50				Photo Pan, Description	2	
0+52				Sample	8	
1+00		Double Core	7	Double Core	7	
1+07	a-b	Travel (4 fps)	3	Travel (4 fps)	3	700
			STATION b/bend (7/2 min)			
1+10	b	Photo Pan	2	Description	2	
1+12		Sample	5	Sample	5	
1+17	b-bend	Travel (4 fps)	3	Travel (4 fps)	3	700
1+20	bend	Photo Pan	2	Description	2	
1+22	bend-c	Travel (2 fps)*	16+	Travel (2 fps)	16+	1600
			STATION c (30 min)			
1+38	c	Photo Pan	2	Description	2	
1+40		Sample	4	Sample	4	
1+44		Proceed to South Rim (sampling)	7	Proceed to South Rim (sampling)	7	400
1+51	c(south)	Sample Boulder Tracks	5	Sample Boulder Tracks	5	
1+56		Film CDR & Bldr Rolling	5	Roll Boulders	5	
2+01		Document CDR position	5	Go behind boulder	5	
2+06		Photo Pan	2	Site description	2	
2+08	c-d	Travel (2 fps)** (sampling)	7+	Travel (2 fps)** (sampling)	7+	850
			STATION d (8 min)			
2+15	d	Photo Pan	2	Site Description	2	
2+17		Sample	6	Sample	6	
2+23	d-e	Travel (2 fps)**	11-	Travel (2 fps)**	11-	1050
			STATION e (25 min)			
2+34	e	Set up Camera	1	Trenching	10	
2+35		LPM Measurement	9			
2+44		Photo Trench	2	Photo Trench,Bootprint	2	
2+46		Sample Trench (SESC)	3	Sample Trench (SESC)	3	
2+49		Sample	10	Sample	10	
2+59	e-f	Travel (4 fps)**	6+	Travel (4 fps)**	6+	1050
			STATION f (15 min)			
3+05	f	Photo Pan	2	Site Description	2	
3+07		Sample	3	Sample	3	
3+10		Triple Core	10	Triple Core	10	
3+20	f-g	Travel (4 fps)	2+	Travel (4 fps)	2+	500
			STATION g (7 min)			
3+22	g	Photo Pan	2	Site Description	2	
3+24		Sample	5	Sample	5	
3+29	g-LM	Travel (4 fps)	5	Travel (4 fps)	5	775
			AT LM (41 min)			
3+34	LM	Contaminated Sample	6	Contaminated sample	6	
3+40		Closeout	12	Closeout	25	
3+52	EVA Terminate		23			
4+05				EVA Terminate	10	
			4+15		4+15	

* Includes three one-minute rests. ** Includes one one-minute rest.

FIGURE 7

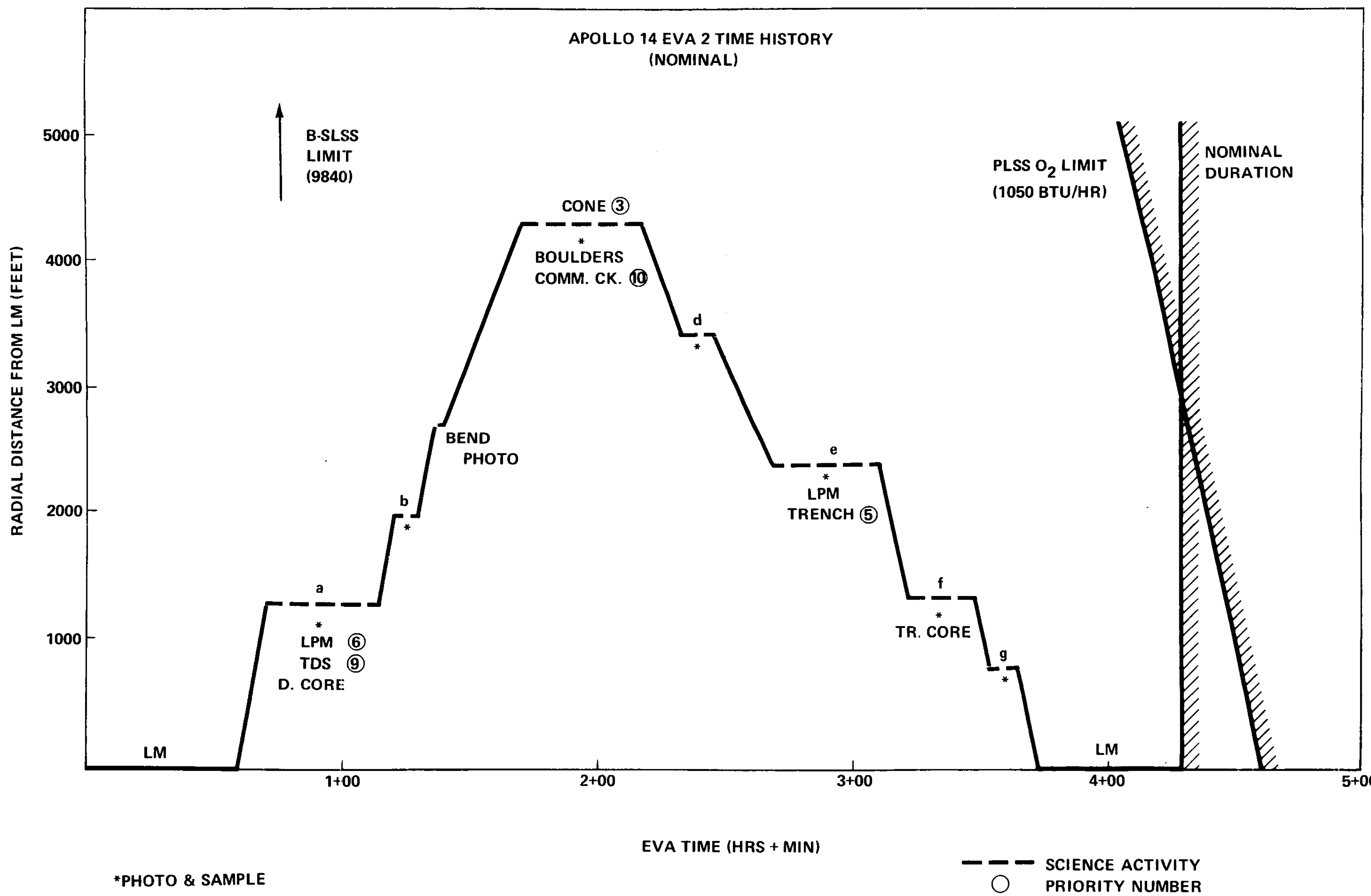

APOLLO 14 EVA 2 TIME HISTORY
(NOMINAL)
B-SLSS
LIMIT
(9840)
CONE ③
*
BOULDERS
COMM. CK. ⑩
PLSS O_2 LIMIT
(1050 BTU/HR)
NOMINAL
DURATION
5000
4000
3000
2000
1000
RADIAL DISTANCE FROM LM (FEET)
a
*
LPM ⑥
TDS ⑨
D. CORE
b
*
BEND
PHOTO
d
*
e
*
LPM
TRENCH ⑤
f
*
TR. CORE
g
*
LM
LM
1+00
2+00
3+00
4+00
5+00
EVA TIME (HRS + MIN)
*PHOTO & SAMPLE
SCIENCE ACTIVITY
PRIORITY NUMBER

FIGURE 8

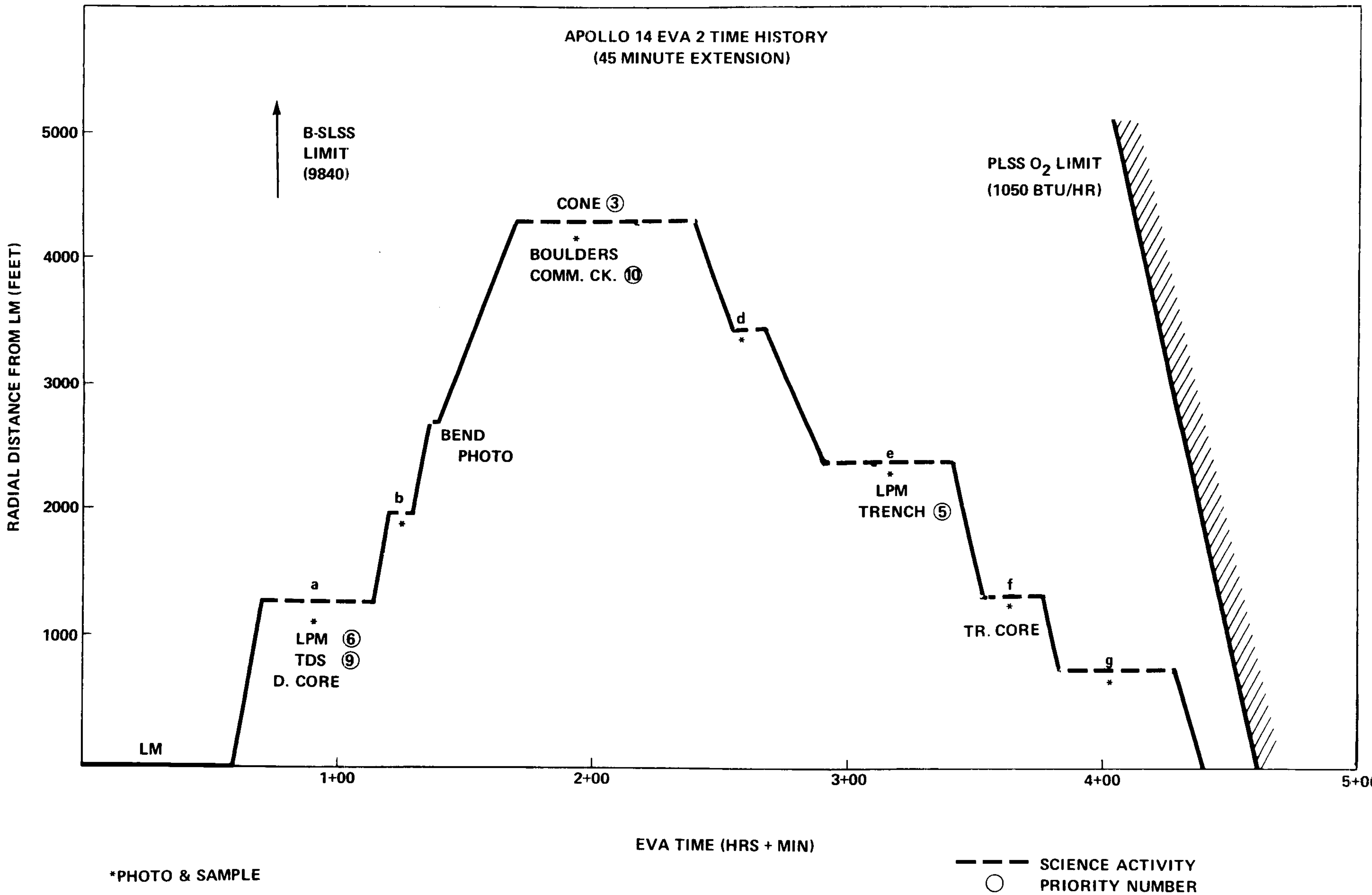

APOLLO 14 EVA 2 TIME HISTORY
(45 MINUTE EXTENSION)
B-SLSS
LIMIT
(9840)
5000
4000
3000
2000
1000
RADIAL DISTANCE FROM LM (FEET)
CONE 3
*
BOULDERS
COMM. CK. 10
PLSS O_2 LIMIT
(1050 BTU/HR)
d
*
BEND
PHOTO
b
*
e
*
LPM
TRENCH 5
a
*
LPM 6
TDS 9
D. CORE
f
*
TR. CORE
g
*
LM
1+00
2+00
3+00
4+00
5+00
EVA TIME (HRS + MIN)
*PHOTO & SAMPLE
SCIENCE ACTIVITY
PRIORITY NUMBER

FIGURE 9

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Case 320

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